

Sharing the Wealth

Towards an Ocean Sensing Network

Autonomous Underwater Vehicles (AUVs) and associated undersea technologies have demonstrated exceptional current utility and great growth potential for military, governmental and commercial maritime agencies as well as for ocean research institutions. While sustained and aggressive research, development, testing and evaluation is still in order, the technology is available now to benefit potential consumers with the incredible range of data these systems can already provide. Although unmanned systems in other domains (air, ground, and space) have experienced rapid growth resulting from wartime necessities, there remains a prevalent 'wait and see' mindset about unmanned undersea systems among those who work in and depend on the oceans.

The drive for 'bigger, better, faster, cheaper' systems is understandable, but AUV manufacturing and operational expertise are niche commodities that require constant and consistent cultivation to maintain. Rather than continuing to impose the cost of development on government and military organisations, as is the traditional practice, or of imposing the cost of ownership on agencies that cannot afford the initial expense, existing systems can be employed across the world today to offset those costs by the creation of a pay-for-access network to share the wealth of data that is already available.



Rand LeBouvier,
Bluefin Robotics
Corporation, USA



Donald Steinbrecher,
Naval Undersea
Warfare Center,
Newport, RI, USA

Evolving global realities prove that there is a real and present demand for information about the ocean environment to allow response to changing economic and climatic conditions and to provide security for ports, harbours and shipping lanes in a world that is increasingly dependent on the uninterrupted flow of maritime commerce. Myriad unmanned systems deployed worldwide and connected via an overarching data network can provide persistent presence and access to information for a wide audience of users. There is a possible practical and cost-effective approach to creating such a network. There is no intent, however, in this short discussion to address treaty obligations such as those that might be imposed by UNCLOS III or legal and insurance issues, which must eventually be addressed.

As background, AUVs offer significant advantages in comparison to manned or towed systems. Due to their inherent stability of flight and ability to

maintain precise altitude above the sea bottom, AUVs are better able to provide higher quality imagery. Their stability of flight also contributes to the high degree of accuracy that can be achieved in AUV navigation, which in turn enables the repeatability of surveys; the AUV is quite

adept at returning to previous survey waypoints and at re-creating previous tracks. AUVs consistently demonstrate a higher coverage rate and attendant shorter survey time.

Obviously, there are significant manpower and resource savings to be

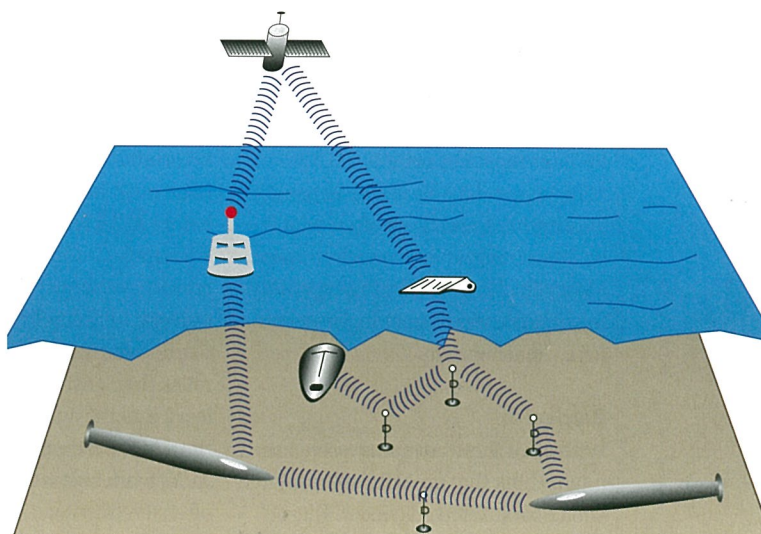
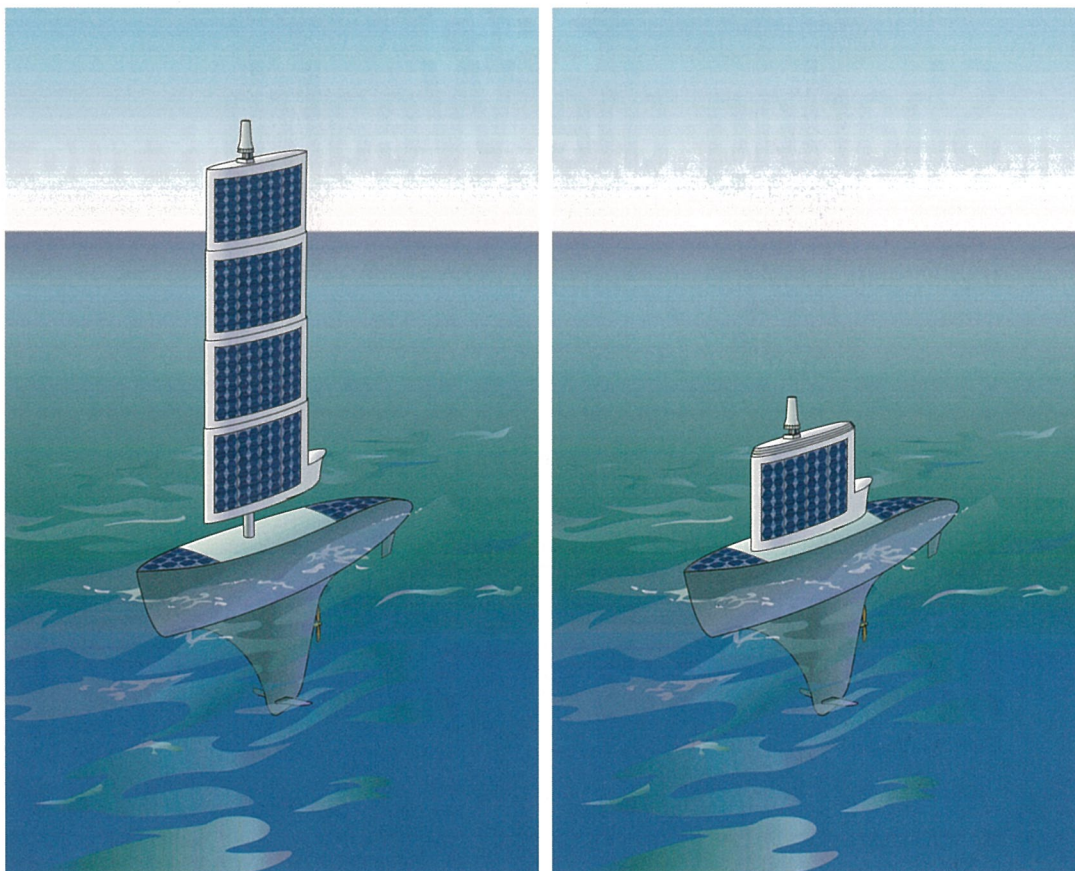


Figure 1: The UNDERNET is a Multi-Environmental, End-to-End Communications Network. (Source: UNDERNET concept from NUWC, Newport, RI, developed in association with Battelle Memorial Institute and Bluefin Robotics Corporation)

Report Documentation Page			Form Approved OMB No. 0704-0188		
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE AUG 2012	2. REPORT TYPE		3. DATES COVERED 00-00-2012 to 00-00-2012		
4. TITLE AND SUBTITLE Sharing the Wealth Towards an Ocean Sensing Network			5a. CONTRACT NUMBER		
			5b. GRANT NUMBER		
			5c. PROGRAM ELEMENT NUMBER		
6. AUTHOR(S)			5d. PROJECT NUMBER		
			5e. TASK NUMBER		
			5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Bluefin Robotics Corporation,553 South Street,Quincy,MA,02169			8. PERFORMING ORGANIZATION REPORT NUMBER		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSOR/MONITOR'S ACRONYM(S)		
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)		
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 4	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

Figure 2: 'Sea Satellites' use multiple energy sources and reduce exposure in high sea states.



realised immediately. There is no need to constantly monitor the AUV during its mission, and the host vessel does not need to 'mow the grass' and thereby waste fuel and human capital any longer. Rather, the expense of maintaining a ship and crew on station, in unco-operative weather, is largely avoidable. This means a direct reduction in the cost of operation and in exposure to the exigencies of unfriendly sea conditions. Further, for port security and inland survey purposes, there is no need to close busy waterways (with the immense expense that this could entail) to perform missions.

Perhaps most importantly, AUVs offer tremendous flexibility in payload options, and these often might be interchangeable, even while at sea. Most vehicles also offer the capability to employ more than a single sensor for a single mission.

Barriers

With all of these advantages, one might think that an AUV is an easy choice for interested clients. The reality is that there are still ponderous barriers to their more widespread acceptance and use. First, and

perhaps most daunting, is the initial cost of investment for the purchase of an AUV. The adage that, 'you get what you pay for,' is abundantly true in the AUV manufacturing field. If you wish to have a highly capable system that reliably returns after its missions in the most challenging environment in the world, then you can expect to pay a premium for that. If you wish to explore the deepest ocean depths and return with superb quality data and imagery, then you want an equally superbly engineered system to do that for you.

The fear of losing an expensive asset is certainly comprehensible, and this issue must be addressed at every level before AUVs will be used to maximum advantage. Oddly enough, military crews have shown the most reluctance to fully employ AUVs, while academic institutions have logged more miles than anyone else to date. I will leave it to the audience to deduce the source of that phenomenon, but AUVs work best when you use them often. Frequent use, of course, breeds familiarity and confidence. Those who use the vehicles most will be the first to discover new ways of using them.

Yet, the requirement for undersea data is increasing and shows little sign of abating as the promise of access to previously inaccessible oceanic resources and the criticality of maintaining secure and open sea lanes and ports is realised globally. There is already a prodigious amount of data that has been collected and severely under-used that could be made available to wider audiences who cannot afford the investment in expensive equipment. Access to this data could be made available on a pay-for-use basis, and the proceeds from that use could offset the expense of developing, manufacturing, and operating vehicle systems.

Enablers

While the barriers to use are considerable, there are enablers for more insatiable consumption of AUV-provided data. Consumers really have little regard from which platform the data is obtained. Rather they are focused on three things that one might call 'freshness, ripeness, and taste,' similar to a shopper selecting produce. The data must be obtained in a timely manner (not necessarily 'new' data), it must be ready for

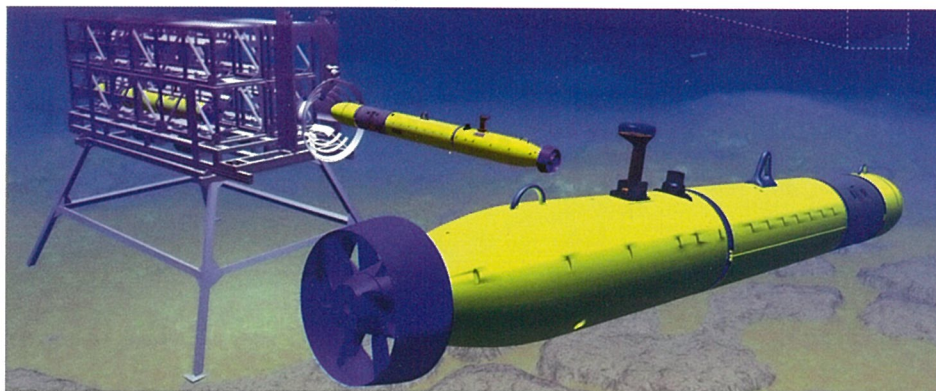


Figure 3: AUVs could be widely deployed using undersea docking stations.

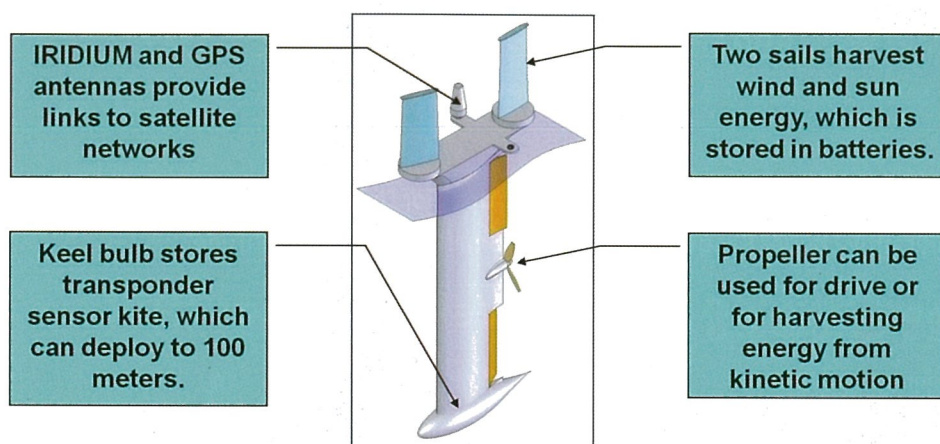


Figure 4: MIT concept for a Long-Endurance, Energy-Harvesting ASV.

consumption (accessible via common information nodes), and it must be of high quality. Older data can prove very satisfactory, especially in discovering trends (change detection, migratory habits, reef generation or degeneration, and much more). Those with proper resources and funding can ensure that the AUV industry continues to flourish, while receiving compensation for their investment through the sale of valuable data. As more vehicles are built to accommodate the demand for

collection, military use, commercial use and individual users.' This vision is certainly more inclusive in terms of access than some other current concepts for undersea observatories that have been proposed. It is undeniably ambitious in its scope, but as you will see, quite practical in implementation.

The UNDERNET will employ autonomous surface nodes designed to harvest wind, wave, and solar energy for endurance and persistence. The data

The surface nodes are networked by satellite and have constant GPS connectivity, so that each surface node has immediate positional and near real-time situational awareness. They can be commanded to reposition from either an earth satellite or an unmanned surface or subsurface platform. Thus, the network could be redeployed as requirements dictate or evolve. The nodes would be designed to submerge as a safety measure to avoid potentially damaging weather and seas.

The UNDERNET business model is akin to that used for Commercial Satellites, although a bit more accessible, tailorable, and reasonably priced. The whole system accounts for means to:

- allocate resources to collect data
- communicate with platforms collecting that data
- assemble, process, evaluate, disseminate and display data and
- control levels of access

The physical composition of the system includes:

- 'Sea Satellites' or surface nodes (Figure 2)
- Unmanned Maritime Systems (AUVs and USVs)

AUVs offer tremendous flexibility in payload options

data, the unit prices of these systems will surely decrease.

Vision and Implementation

The vision for an ocean sensing network (Figure 1) is: 'An under-sea communications network with all the features of the Internet for underwater communications, data

collectors will consist of a network of undersea and surface vehicles and deployed sensors that glean positioning information and mission updates from known surface nodes and that can continue on mission without frequent surfacing. They can also download data to those nodes for dissemination.

- Undersea Docking Stations (Figure 3)
- Deployed sensors

The virtual components would include:

- Network
- Interfaces and
- Functionality

Sea Satellite Concept

One particular concept for the actual surface node is the MIT Sea-Grant Autonomous Surface Vehicle (ASV) design that comprises a composite vertical fin having a bottom-mounted bulb ballast, a surface body fitted with two solid-wing-design folding sails that double as solar panels, a GPS and satellite-communications antenna, and a water-propulsion system comprising a motor-driven propeller and two actuator-positioned rudders. When outfitted with a full complement of batteries, the vehicle is about 8ft tall and weighs about 100lbs.

According to preliminary estimates, the ASV can maintain its position in moderate seas within 250m of a fixed location while using, on average, 1.5

enjoy the added benefit of being able to task the platforms and sensors to conduct surveys. Persons requiring certain data could post their requirements on the site, and equipment owners/operators could offer their services via private bid. It stands to reason that if the response is strong, additional systems will be manufactured and additional service providers will enter the market.

Although there are quite a few obvious applications that could benefit from the creation of UNDERNET, the 'Killer Applications' are predicted to be Port and Harbour Security, Oil and Gas survey and pipeline inspection, and Anti-Submarine Warfare (ASW) / Anti-Surface Warfare (ASUW) operations.

The great promise of an Ocean Network lies in its accessibility to a wide audience. The physical equipment used in the system is important, but the technology readiness level of that equipment is quite well-established with few exceptions. Rather, it is the organisation of the network and its administration that will provide the challenges; maintaining

The great promise of an Ocean Network lies in its accessibility to a wide audience

Watts of energy. Energy harvested from solar panels and wind is stored in batteries to provide energy for communications and for other on-board systems.


The UNDERNET concept directly addresses the cost of ownership of currently expensive unmanned maritime systems. Through a fee-for-service arrangement, it is conceivable that the investment made by vehicle manufacturers and survey service providers could be recovered within the first year of operation. Those fees could include direct lease of the nodes, vehicles, and sensors, or simply access to data archived on the network. Direct lessees would

connectivity, allowing scalable levels of access, enabling tailoring and tasking of data requirements, and creating a standing, expandable database will generate immediate value and will add new users on an unprecedented scale.

Acknowledgements

This article was made possible through the work performed under a Cooperative Research and Development Agreement (CRADA) between Battelle Memorial Institute and the Naval Undersea Warfare Center (NUWC) in Newport, Rhode Island to jointly address an undersea communications system with independent power and broad coverage with the

following contributors in these roles:

- NUWC Newport RI (End to End Communications, Large Networked Undersea Systems)
- Battelle Memorial Institute (System Integrator, Hardware Development, Hardware Builder, System Operator). Dr. Lynn Faulkner, Ph.D. Battelle Program Manager
- Bluefin Robotics Corporation (Technical Support, Operations, Proof of Concept, and Manufacturing)
- Massachusetts Institute of Technology (Naval Architect)
- University of Michigan (Efficient Propeller Supplier). 

The Authors

Dr. Rand LeBouvier, a retired Navy Captain, is in charge of government and military business development at Bluefin Robotics, and was the commissioning Commanding Officer of the USS *Carter Hall* LSD-50 and the first head, Unmanned Aerial Vehicles (UAV) Section in the Air Warfare directorate in the Office of the Chief of Naval Operations in Washington D.C. He is a 1978 graduate of the United States Naval Academy, the United States Marine Corps Command and Staff College, the University of Rhode Island (Masters in Marine Affairs), the Naval War College (Masters in National Security and Strategic Studies and first prize in the AFCEA C4I category for paper *Extending Operational Reach With Unmanned Systems*), and Salve Regina University (PhD thesis on the significance of embodiment to the development of Artificial Intelligence).

Dr. Donald H. Steinbrecher Dr. Steinbrecher received a BSEE degree, with highest honors, from the University of Florida in June 1960. He entered the Massachusetts Institute of Technology graduate studies programme in Electrical Engineering and Computer Science and received a Master of Science in 1963 and completed the PhD degree in June 1966. Dr. Steinbrecher established a fundamental performance limit for the dynamic range of frequency converters in 1975, which resulted in two patents defining the Paramixer™ frequency translator. The Paramixer became the core technology for the development of numerous broadband software-defined signals acquisition systems. Dr. Steinbrecher was named a winner of the 2007 Department of the Navy Top Scientists and Engineers of the Year Award for his innovative work in the field of high-performance digital signals acquisition systems. He is also a winner of the 2007 Chief of Naval Research Million-Dollar Challenge. Dr. Steinbrecher founded Steinbrecher Corporation which became a leading supplier of software-defined signals acquisition systems. Dr. Donald H. Steinbrecher currently holds the position of chief scientist in the Electromagnetic Systems Division of the Navy Undersea Warfare Center in Newport, RI where he has been employed for the past 10 years.